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IMPORTANCE OF BYCATCH IN THE NORTHERN SHRIMP FISHERY IN THE ESTUARY AND NORTHERN GULF OF ST. LAWRENCE

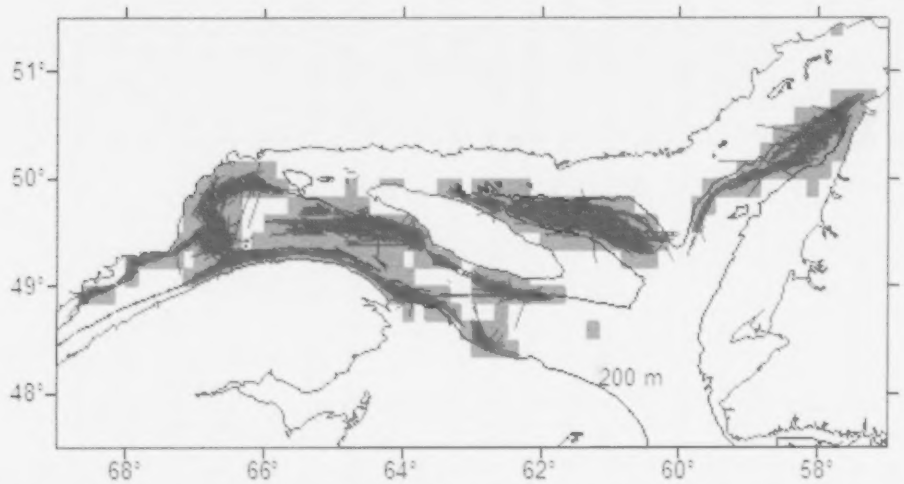

Figure 1. Distribution of cumulative fishing effort (>120 hours) from shrimpers by fishing square and of fishing tows sampled by at-sea observers, from 2000 to 2011.

Context

The Northern shrimp fishery is carried out using otter trawls with a minimum mesh size of 40 mm. The mandatory use of a separator grate during fishing operations since 1993 has led to a significant reduction in catches of large fish. However, small fish may be retained by the trawls and are considered bycatches.

In compliance with the United Nations Food and Agriculture Organization's (FAO) Code of Conduct for Responsible Fisheries, the Department of Fisheries and Oceans (DFO) promotes responsible fishing aimed at reducing bycatches and mitigating impacts on habitat wherever biologically justifiable and cost-effective. The DFO Policy Framework on Managing Bycatch and Discards (currently under development) aims to ensure that Canadian fisheries are managed in a manner that supports the sustainable harvesting of aquatic species by 1) Minimizing the risk of fisheries causing serious or irreversible harm to bycatch and discard species, and 2) Accounting for total catch, including bycatch and discards.

The northern shrimp fishery in the Estuary and Gulf of St. Lawrence has been certified sustainable and properly managed according to the Marine Stewardship Council (MSC) criteria for wild fisheries. However, the current certification is subject to certain conditions focusing on determining the impact of trawls used. This document summarizes the available information on fishing activities in order to assess the impact of bycatches on species stocks that are not targeted by the shrimp fishery.

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SUMMARY

- The shrimp fishery is carried out using small-meshed trawls that catch and retain several fish and marine invertebrate species. Although large fish are released from trawls due to the mandatory use of a separator grate since 1993, catches still contain a certain number of small specimens.
- Bycatches in the shrimp fishery were estimated using at-sea observer data for the 2000–2011 period (14 185 fishing tows). Catches noted by observers were weighted by total fishing effort in order to extrapolate the results to the entire shrimp fleet.
- Bycatches represent between 1.0 and 2.3% (in weight) of Northern shrimp catches for the entire period. Bycatches noted by observers were grouped under 97 taxa. A total of 16 of these were present in at least 10% of the tows whereas 59 were observed in less than 1% of the tows.
- The 10 most common species are Greenland Halibut, capelin, redfishes, Atlantic herring, American plaice, witch flounder, barracudina, thorny skate, Atlantic hagfish and marlin-spike. The 10 species with the largest bycatches (in weight) are capelin, Greenland Halibut, Atlantic herring, redfishes, American plaice, white shrimp, witch flounder, Atlantic cod, thorny skate, and barracudina.
- Bycatches of the most common groundfish species were compared with the results of the research survey in the Estuary and the northern Gulf of St. Lawrence for the same size ranges. Bycatches represent less than 1% in number and weight of the survey abundance and biomass estimates for each species.
- Catches of pelagic fish and invertebrates cannot be compared to the survey results. For the species that are harvested, there are much fewer bycatches than commercial landings. Bycatches of the other species that are not harvested totaled only a few tons over 12 years.
- Bycatches of vulnerable species (found in less than 0.25% of the fishing tows) and species at risk (found in 0.4% of the tows) are considered marginal compared to northern Gulf populations because they range from a few specimens to a few hundred kilograms per year.
- Although bycatches in the shrimp fishery are frequent and diversified, they remain low and should not have had an impact on Estuary and northern Gulf populations for the 2000–2011 period. Bycatches contribute to increasing mortality, but this increase is marginal in relation to the normal mortality rate for these populations.

INTRODUCTION

In the Gulf of St. Lawrence, the only type of authorized Northern shrimp (*Pandalus borealis*) fishing is commercial fishing practiced with a trawl. Since 1986, a minimum mesh size of 40 mm has been in force to minimize catches of small shrimp and more closely target the size of shrimp caught to market demand. Separator grate use became mandatory for all fishers in the winter of 1993 in order to greatly reduce accidental groundfish catches. The separation system must be inserted into the trawl's lengthening piece. It includes a funnel or guiding panel, a rectangular separator grate with spacing of between 19 and 25 mm between the vertical rods and a triangular orifice on top of the lengthening piece that must be left completely open in order to facilitate the escape of fish from the trawl.

Although large individuals have been released from the trawl through mandatory use of a separator grate, a certain number of small specimens remain in the catches. The DFO *Policy Framework on Managing Bycatch and Discards* (currently under development) applies to retained and discarded bycatches; i.e. a) any retained species or specimens that the fisher was

not licensed to direct for but is required or permitted to retain, and b) all discards, including catches released from gear and entanglements, whether alive, injured or dead, and whether of the target species or the non-target species. In short, enforcement of the policy requires two primary tasks: 1) Documenting the composition and size of bycatches in all fisheries, and 2) Assessing whether their nature and scale pose concerns for sustainability of the population.

This document summarizes the available information on shrimp fishing activities in the Estuary and Gulf of St. Lawrence for the 2000–2011 period in order to assess the impact of bycatches on species stocks that are not targeted by the shrimp fishery.

Input Data

The study area is the Estuary and northern Gulf of St. Lawrence (Figure 1). Few to no concentrations of *Pandalus borealis* are found south of the Laurentian Channel. As a result, the commercial fishery has developed almost exclusively in the Esquiman and Anticosti channels and along the two Laurentian Channel watersheds up to the Estuary. Traditional fishing grounds are located at depths of 200 to 300 m.

Shrimpers are obliged to have an at-sea observer on board at the Department's request. The At-Sea Observer Program aims at 5% coverage of all shrimper fishing trips. These observers record detailed information on tows (position, duration, and catch per species or taxum and, for some species, specimen length). Data from the At-Sea Observer Program that were used for this study were collected between 2000 and 2011 and represent 14 185 fishing tows for a total effort of 65 018 hours (Figure 1).

Organisms that were identified on vessels by observers correspond to 281 taxa, 191 of which are fish and 90 of which are marine invertebrates. Marine organism identification is difficult for non-commercial species or species that are rarely caught, especially when specimens are small, for example when they are in bycatches in the shrimp fishery. The list of taxa noted by at-sea observers between 2000 and 2011 was reduced to 98 by combining the observations that likely correspond to one species or to those that are similar or easily confused.

To extrapolate the results of observer sampling to the entire shrimp fleet, the at-sea observer data and the fishing effort from the shrimpers were combined according to NAFO unit area and shrimp fishing area. Bycatches in tows in the same weighting cell were totaled and weighted by fishing effort. Annual bycatches for the entire study area correspond to the total annual catches in the weighting cells.

Bycatches in the shrimp fishery were compared with biomass and population number estimates from the DFO trawl survey in the Estuary and northern Gulf of St. Lawrence between 2000 and 2011. Biomass and population numbers were estimated using the swept area method over a total standard area of 116 115 km².

ANALYSIS

Observer deployment

The distribution of observers in various mobile- and fixed-gear fisheries, including the shrimp fishery, in the Gulf of St. Lawrence was recently studied (Benoît and Allard 2009). According to this study, observer deployment is not significantly random in most fisheries, with the exception of Atlantic halibut, shrimp and winter flounder. Moreover, the difference between the estimated shrimp catch according to observer data and the official landings is only 2%, which indicates that observer deployment in the shrimp fishery had no effect on fishing behaviors and that the observation results can be extrapolated to the entire fleet.

Bycatch composition

The ratio of all bycatches in weight compared to Northern shrimp catches ranged between 1.0 and 2.3% per year between 2000 and 2011 (see table below). The vast majority (87%) of bycatches were not retained, while only 0.1% of Northern shrimp catches were discarded. The target species (Northern shrimp) was caught in 99.9% of all fishing tows carried out in the presence of an observer.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Ratio (%)	1.7	1.4	2.3	1.9	1.7	1.2	1.2	1.0	1.5	1.3	1.6	1.5

Bycatches were grouped under 97 taxa (Table 1). A total of 77 taxa are fish and 20 are invertebrates. The taxa have variable taxonomic levels ranging from species for 57 fish and five invertebrates, to genus (e.g. *Myoxocephalus*) or phylum (e.g. Porifera). Occurrence and bycatches were estimated for each taxum and each year from 2000 to 2011. A total of 16 taxa were present in at least 10% of the tows whereas 59 taxa were observed in less than 1% of them. The 10 most common species are Greenland halibut, capelin, redfishes, herring, American plaice, witch flounder, barracudina, thorny skate, hagfish and grenadier. The 10 species with the largest bycatches (in weight) are capelin, Greenland halibut, herring, redfishes, American plaice, white shrimp, witch flounder, Atlantic cod, thorny skate, and barracudina.

Table 1. Bycatches (kg) in the shrimp fishery in the Estuary and northern Gulf by year and occurrence (%) of taxa, 2000–2011.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Occurrence (%)
Greenland halibut	121193	86420	100758	94405	60678	64183	82075	86307	121310	64608	70836	82886	89.581
Capelin	120863	77251	305938	136014	310669	219101	94278	87189	92669	321693	156020	210623	82.566
Redfishes	44150	38416	38792	38904	14305	24252	45823	23571	26021	9755	11550	10042	68.967
Atlantic herring	75512	36641	35545	40403	76323	49478	31910	23796	25084	56717	31694	66035	67.621
American plaice	11046	12107	17818	18501	42992	19687	20715	19117	23105	17492	39224	26197	56.673
Witch flounder	31888	10249	7297	15855	10638	2548	9311	13240	19168	17053	19288	20205	43.941
White barracudina	725	1985	6566	3658	12921	1441	6089	3969	19982	17633	10540	8468	37.081
Thorny skate	7637	5542	6060	5269	11070	5599	7580	7751	12018	5005	19597	8320	34.699
Atlantic hagfish	4104	3009	2481	2100	2540	1424	3122	2792	2754	4067	3548	3713	27.719
Marlin-spike	2544	1180	763	1868	2856	629	934	2366	3618	2040	2123	1679	25.196
Eelpouts	2982	2622	2218	7365	6537	1858	6159	4298	5554	4800	6905	4951	23.877
Atlantic cod	4597	9659	3285	10137	7935	2629	4434	4883	45151	11402	3105	8983	21.135
Sand lances	13434	6181	2937	2108	7837	3368	658	2627	4339	756	223	347	12.189
4-beard rockling	412	308	167	1766	430	229	2890	433	1389	423	721	1213	11.153
Blennies	279	147	502	512	539	835	2340	3420	5585	4323	1278	2204	10.497
Squids	243	222	679	901	3062	326	4455	2712	1195	368	972	798	10.342
Poachers	144	85	26	73	592	81	84	163	378	109	1025	184	7.846
White hake	579	203	223	879	629	177	1130	1778	1096	929	676	493	7.085
Silver hake	127	524	165	153	98	41	340	889	547	172	1312	924	6.902
White shrimp	18930	40607	30275	13201	7025	682	371	56301	1796	22000	40968	7455	6.606
Smooth skate	95	1152	85	455	195	96	246	213	642	411	475	1637	4.265
Arctic cod		187	3843	97	1279	444	804	2414	123	2877	971	609	3.962
Atlantic soft pout	1	44	30	30	43	11	12	84	190	450	213	100	3.856
Octopuses	10	134	26	70	95	109	13	856	853	607	1096	338	3.849
Anemones	25	40	77	106	226	264	243	74	528	311	368	219	2.961
Snow crab	93	30	16	42	235	185	120	79	316	129	197	70	2.545
Sea stars	195	133	26	565	281	172	155	50	536	278	220	52	2.531
Atlantic halibut	3298	3107	2314	3292	2121	1007	923	2194	1710	2418	6676	3654	2.333
Sculpins (*Myoxocephalus*)	564	585	84	919	947	428	49	593	75	878	499	420	2.326
Spiny tail skate	273	369	729	1069	580	62	72	316	949	53	332	565	2.298
Snailfishes	707	89	17	35	499	341	542	340	1085	925	427	334	2.256
Lumpsuckers	82	45	51	556	139	45	65	169	149	239	114	91	1.854
Jellyfishes	186	81	28	34	114	9	344	19	45	580	12179	222	1.762
Wrymouth	8	18	12	492	35	2	4	15	845	48	55	67	1.643
Rocklings	4	9		843	189	8	79	1607	663	107	109	3	1.636
Lumpfish	293	2	8	90	12	21	38	43	99	22	21	41	1.480
Hookears		22	128	30	38	242	329	22	85	217	12	47	1.283
Sculpins (*Triglops*)		111	23	307	176	306	221	57	686	201	161	280	1.029
Winter flounder		101		755	15	12	55	107	969	268	49	1032	0.853
Atlantic wolffish	319	67	92	67	148	12	52	464	58	39	69	134	0.818
Light fishes	145	243	192	84	167	301	90	198	67	73	225	460	0.804
Longfin hake	33	196	35	104	107		164	329	353	391	45	161	0.740
4-line blenny				12	154			11	775	12	146	1102	0.649
Hatchet fishes	34	249	177	78	194	167	76	234	49		179	321	0.627
Rainbow smelt		22			112		15	226	365	12	35409	128	0.613
Atlantic mackerel	81			21		55	8	42	978	236	58		0.592
Greenland cod	645	54			12		236			7	1052	121	0.571
Winter skate	5			46	66		41		58	75		759	0.529
Ocean pout	149		1	41	13	4		3		13	29	7	0.451
Spiny dogfish	46	99		1489	10		29		40		72		0.430
Bobtails								407	190	286	229	98	0.430
Urchins	11	66	9	29	38	152			251	501	180	65	0.409
Spotted wolffish	86	75	34	70	48	353	24	123			16	80	0.367

Importance of Bycatch in the Northern Shrimp Fishery in the Estuary and Northern Gulf of St. Lawrence

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Occurrence (%)
Striped shrimp	7314			47		2922	812	220	70	16908	91	40591	0.360
Sticklebacks	28	44	50	146	76	43	41	22	227	37	88	98	0.331
Black dogfish	41	277	64	216	10		20	28	48	10	8	18408	0.317
Slender snipe eel			101	89	32	55	31	116	324	34	15	33	0.310
Crabs *Hyas*	43			43	126	43	61	88	53	127	65	31	0.310
Other shrimps							15		106	223	6736	235	0.303
Sea pens									135	570	34	48	0.254
Sponges	71		188	30	52		37		35	29	140	64	0.211
Yellow tail flounder			23	337	21	87	41		17			13	0.183
Haddock				12	14		16				357		0.176
Monkfish		37		44	14			123	272			24	0.148
Bivalves				55	24	20	39		71	48	79	8	0.141
Sea cucumber	15	26		22		33	12		69	22	120		0.141
Pollock								321					0.134
Brittle stars					24	23			68	116	85	23	0.134
Sea lamprey	15	55		48	36	11	50	38	28		15	50	0.120
Arctic staghorn sculpin							45		216		15		0.099
Stout sawpalate	26		15		50						28	109	0.099
Tomcod				44		4	241		104			10	0.070
American eel	86				24					22		23	0.063
Atlantic argentine			69270	44						12			0.056
Northern wolffish						45		171			18		0.042
Slatjaw cutthroat eel								75		24			0.042
Lightfishes					14			54				38	0.042
Rock gunnel							62	20					0.035
King crab		24				11	30					13	0.035
American shad	12	77			14							8	0.028
Atlantic salmon	30	89											0.028
Blue whiting		26	17							12			0.028
Boa dragonfish				22			16	14	17				0.028
Rock crab	21								70		20		0.028
Polar sculpin									104				0.021
Fish doctor		26				11				12			0.021
Atlantic Saury							31		35				0.021
Manylight viperfish				22							28		0.014
Anglers			17					20					0.014
Sea raven										25		8	0.014
Dragonfishes								11		12			0.014
Basket stars									17	19			0.014
Striped bass													0.007
Round skate				22									0.007
Sculpins (*Icelus*)												8	0.007
Butterfish										12			0.007
Mummichog									28				0.007

Bycatch size

The bycatches were compared to the results of the research survey for the most common species. A fine-meshed shrimp trawl was used to conduct this survey. The survey trawl catches a good number of small individuals, including juveniles or adults depending on the species. Although the selectivity of the trawls in the survey and the fishery and the catchability of the species are not known, it is assumed that the survey results represent a minimum estimate of the abundance of these species in the Estuary and the northern Gulf of St. Lawrence and that the comparison between the fishery and survey results represents a cautious approach. It is quite likely that the catchability in the survey is less than one and thus that the ratio of the bycatch of the shrimp fishery to the abundance of the same species is overestimated.

Groundfish

Length frequencies are available for five taxa (Figure 2). Redfish species were grouped under one taxum because observers cannot tell the species apart on board a vessel.

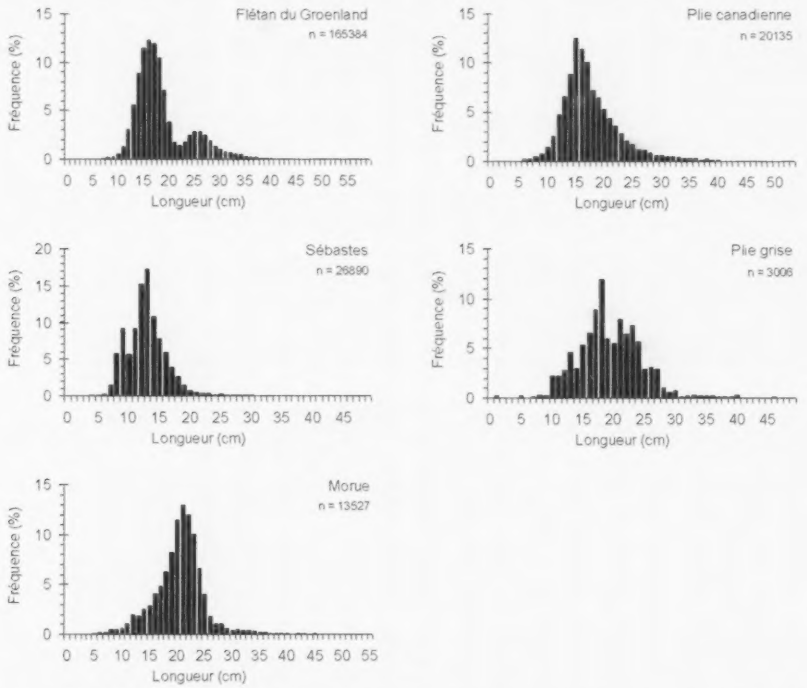

Figure 2. Length frequencies for groundfish that were sampled by observers during the 2000–2011 shrimp fishery. The number (n) of specimens that were measured is shown.

Abundance and biomass were estimated from the survey for the portion under the size threshold determined for each species. This was done to compare the same size ranges between shrimper and survey catches. Bycatches of Greenland halibut, redfishes, American plaice, witch flounder and Atlantic cod represent less than 0.9% (in number) and less than 0.6% (weight) of the survey biomass and abundance estimates for fish under the size threshold (Table 2).

Table 2. Survey abundance and biomass estimates for fish under the size threshold, bycatches in number and weight and ratio of bycatches to survey estimates for Greenland Halibut, redfishes, American plaice, witch flounder and Atlantic cod, from 2000 to 2011.

Greenland halibut

	Survey		Bycatch		Bycatch / Survey	
	n x 1000 < 31 cm	tons < 31 cm	n x 1000	tons	n (%)	t (%)
2000	421553	42377	2251	121	0,53	0,29
2001	268487	32066	824	86	0,31	0,27
2002	203532	19057	1535	101	0,75	0,53
2003	457484	55438	1129	94	0,25	0,17
2004	152307	21968	631	61	0,41	0,28
2005	211075	13698	1213	64	0,57	0,47
2006	271867	35618	1137	82	0,42	0,23
2007	206380	19291	1355	86	0,66	0,45
2008	270499	25755	2141	121	0,79	0,47
2009	187236	20671	825	65	0,44	0,31
2010	163595	20007	846	71	0,52	0,35
2011	300890	20363	2317	83	0,77	0,41

American plaice

	Survey		Bycatch		Bycatch / Survey	
	n x 1000 < 30 cm	tons < 30 cm	n x 1000	tons	n (%)	t (%)
2000	592986	31282	160	11	0,03	0,04
2001	276856	12044	267	12	0,10	0,10
2002	65763	3176	501	18	0,76	0,56
2003	582680	30689	577	19	0,10	0,06
2004	195827	13202	1206	43	0,62	0,33
2005	180407	13747	306	20	0,17	0,14
2006	188995	15073	225	21	0,12	0,14
2007	195182	11283	173	19	0,09	0,17
2008	219329	10957	218	23	0,10	0,21
2009	283684	12647	244	17	0,09	0,14
2010	396418	16245	808	39	0,20	0,24
2011	399162	23079	366	26	0,09	0,11

Redfishes

	Survey		Bycatch		Bycatch / Survey	
	n x 1000 < 20 cm	tons < 20 cm	n x 1000	tons	n (%)	t (%)
2000	389919	15465	1230	44	0,32	0,29
2001	230403	7840	880	38	0,38	0,49
2002	167696	7106	427	39	0,25	0,55
2003	272081	13516	910	39	0,33	0,29
2004	151683	8992	235	14	0,15	0,16
2005	4550670	52127	1235	24	0,03	0,05
2006	2006849	58303	1692	46	0,08	0,08
2007	2514451	111063	516	24	0,02	0,02
2008	535906	23092	430	26	0,08	0,11
2009	254584	10067	140	10	0,05	0,10
2010	247974	10459	219	12	0,09	0,11
2011	141144	7602	123	10	0,09	0,13

Witch flounder

	Survey		Bycatch		Bycatch / Survey	
	n x 1000 < 30 cm	tons < 30 cm	n x 1000	tonnes	n (%)	t (%)
2000	131454	7035	385	32	0,29	0,45
2001	62314	3491	231	10	0,37	0,29
2002	30634	1836	129	7	0,42	0,40
2003	95998	5946	522	16	0,54	0,27
2004	60121	3272	156	11	0,26	0,33
2005	48982	3084	30	3	0,06	0,08
2006	43568	2967	130	9	0,30	0,31
2007	55547	3301	100	13	0,18	0,40
2008	70143	3446	607	19	0,87	0,56
2009	61244	2847	301	17	0,49	0,60
2010	91181	5030	158	19	0,17	0,38
2011	61589	4434	177	20	0,29	0,46

Atlantic cod

	Survey		Bycatch		Bycatch / Survey	
	n x 1000 < 30 cm	tons < 30 cm	n x 1000	tons	n (%)	t (%)
2000	54897	4997	91	5	0,17	0,09
2001	55811	7712	85	10	0,15	0,13
2002	14235	2121	14	3	0,10	0,15
2003	97934	14644	90	10	0,09	0,07
2004	34081	4194	64	8	0,19	0,19
2005	27742	2344	33	3	0,12	0,11
2006	84611	9779	96	4	0,11	0,05
2007	49034	5671	34	5	0,07	0,09
2008	126184	17024	463	45	0,37	0,27
2009	53838	7817	160	11	0,30	0,15
2010	26878	2841	45	3	0,17	0,11
2011	62807	8841	123	9	0,20	0,10

There are very few, if any, length frequencies for the other fish species. It is therefore impossible to estimate bycatches in number for these species and only the weight estimates were compared to the survey's biomass estimates for species with an occurrence of more than 1% (Table 1). For some species, biomass was estimated for individuals measuring less than 31 cm, which roughly corresponds to the maximum size of fish caught by shrimpers.

Generally, every year bycatches represent less than 1% of biomass estimates for thorny skate, white hake, smooth skate and lumpfish measuring less than 31 cm and for hagfish, marlin-spike, four-bearded rockling, Atlantic soft pout and Atlantic halibut of all sizes (Table 3). In the case of Atlantic halibut, bycatches are made up of small fish that go through the rods in the grate and large fish that cannot escape out the opening at the back of the trawl. Sand lances are caught regularly in the shrimp fishery (Table 1), but quite irregularly in the research survey. The survey data cannot be used to estimate its biomass. The catchability of sand lance is probably low because of its behavior (it buries itself in the sand) and can probably be caught by shrimpers because it leaves the sea floor at night.

Other groundfish species are caught more or less regularly in the survey. Bycatches of these taxa represent less than 1% of survey biomass estimates since they are conducted using the Campelen trawl in 2006. However, there are a few exceptions (Table 4). Bycatches were 4% for snailfish in 2009, and they greatly exceed survey estimates in the case of Arctic cod and rocklings. Survey estimates for rocklings are quite uncertain because these estimates are based on a very small number of individuals caught (fewer than 10 between 2004 and 2009 and fewer than 20 in 2010 and 2011). Biomass estimates for Arctic cod are based on an average of about 100 individuals. However, their large numbers in bycatches in some years can be due to misidentification, because small individuals can easily be confused with Atlantic cod.

The rest of the groundfish are present in less than 1% of the tows analyzed (Table 1). Estimated bycatches for these taxa range from ten to a few hundred kilograms per year.

Pelagic fish

Some taxa of pelagic fish are caught regularly in the bottom trawl survey and by shrimpers. However, the survey is not suitable for estimating biomass by the swept area method because the catchability of pelagic fish is very low. Capelin bycatches represent between 1 and 10% of annual landings of the species in 4RST between 2000 and 2010, whereas herring bycatches remain well below 0.5% of the landings in 4RS. Barracudinas are not harvested in the Gulf. The other pelagic fish species are caught in less than 1% of the tows observed.

Some catches are still surprising (e.g. 69 t of argentines in 2002 and 35 t of smelts in 2010), but they come from only two tows for the former and one for the latter.

Table 3. Survey biomass estimates for the fish below the size threshold, bycatch in weight and, ratio of the bycatch on the survey estimate for thorny skate, fourbeard rockling, Atlantic softpout, Atlantic hagfish, white hake, Atlantic halibut, marlin-spike, smooth skate and lumpfish from 2000 to 2011.

	Thorny skate			Fourbeard rockling			Atlantic soft pout		
	Survey tons < 31 cm	Bycatch tons	Bycatch/survey t (%)	Survey tons	Bycatch tons	Bycatch/survey t (%)	Survey tons	Bycatch tons	Bycatch/survey t (%)
2000	2786	7,64	0,27	3485	0,41	0,01	178	0,001	0,001
2001	1513	5,54	0,37	1731	0,31	0,02	73	0,044	0,06
2002	1149	6,06	0,53	506	0,17	0,03	120	0,030	0,02
2003	2702	5,27	0,19	4137	1,77	0,04	145	0,030	0,02
2004	2890	11,07	0,38	1504	0,43	0,03	87	0,043	0,05
2005	2801	5,60	0,20	1419	0,23	0,02	141	0,011	0,01
2006	1265	7,58	0,60	1230	2,89	0,24	116	0,012	0,01
2007	1280	7,75	0,61	1415	0,43	0,03	134	0,084	0,06
2008	1619	12,02	0,74	1416	1,39	0,10	123	0,190	0,15
2009	1228	5,00	0,41	1229	0,42	0,03	209	0,450	0,22
2010	1987	19,60	0,99	2053	0,72	0,04	237	0,213	0,09
2011	1393	8,32	0,60	1613	1,21	0,08	236	0,100	0,04
	Atlantic hagfish			White hake			Atlantic halibut		
	Survey tons	Bycatch tons	Bycatch/survey t (%)	Survey tons < 31 cm	Bycatch tons	Bycatch/survey t (%)	Survey tons	Bycatch tons	Bycatch/survey t (%)
2000	12838	4,10	0,03	950	0,58	0,06	875	3,30	0,38
2001	5341	3,01	0,06	720	0,20	0,03	1360	3,11	0,23
2002	3986	2,48	0,06	325	0,22	0,07	1323	2,31	0,17
2003	7739	2,10	0,03	756	0,88	0,12	2597	3,29	0,13
2004	3946	2,54	0,06	650	0,63	0,10	2642	2,12	0,08
2005	3750	1,42	0,04	395	0,18	0,04	3701	1,01	0,03
2006	3282	3,12	0,10	138	1,13	0,82	5249	0,92	0,02
2007	3922	2,79	0,07	254	1,78	0,70	8010	2,19	0,03
2008	3352	2,75	0,08	319	1,10	0,34	16122	1,71	0,01
2009	5030	4,07	0,08	299	0,93	0,31	10160	2,42	0,02
2010	14461	3,55	0,02	506	0,68	0,13	14660	6,68	0,05
2011	6469	3,71	0,06	279	0,49	0,18	12899	3,65	0,03
	Marlin-spike			Smooth skate			Lumpfish		
	Survey tons	Bycatch tons	Bycatch/survey t (%)	Survey tons < 31 cm	Bycatch tons	Bycatch/survey t (%)	Survey tons < 31 cm	Bycatch tons	Bycatch/survey t (%)
2000	5046	2,54	0,05	716	0,10	0,01	177.1	0,293	0,165
2001	2190	1,18	0,05	245	1,15	0,47	73.0	0,002	0,003
2002	1970	0,76	0,04	245	0,09	0,03	182.3	0,008	0,005
2003	4248	1,87	0,04	642	0,46	0,07	322.9	0,090	0,028
2004	3463	2,86	0,08	395	0,19	0,05	96.3	0,012	0,013
2005	4332	0,63	0,01	498	0,10	0,02	342.9	0,021	0,006
2006	2483	0,93	0,04	504	0,25	0,05	732.9	0,038	0,005
2007	3356	2,37	0,07	333	0,21	0,06	832.3	0,043	0,005
2008	3056	3,62	0,12	1104	0,64	0,06	318.3	0,099	0,031
2009	2452	2,04	0,08	302	0,41	0,14	164.8	0,022	0,013
2010	3732	2,12	0,06	343	0,47	0,14	343.1	0,021	0,006
2011	2643	1,68	0,06	230	1,64	0,71	313.2	0,041	0,013

Table 4. Survey biomass estimate, bycatch in weight and ratio of the bycatch on the survey estimate for eelpouts, blennies, Agonidae, silver hake, Arctic cod, sculpins (Myoxocephalus), snailfishes, lumpsuckers, wrymouth, rocklings, hookear sculpins, sculpins (Triglops), Atlantic woolffish, longfin kake and spotted woolffish from 2006 to 2011.

	Eelpouts			Blennies			Agonidae		
	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey
	t	t	t (%)	t	t	t (%)	t	t	t (%)
2006	1714	6,16	0,36	1547	2,34	0,15	199	0,08	0,04
2007	1945	4,30	0,22	876	3,42	0,39	218	0,16	0,07
2008	2126	5,55	0,26	696	5,59	0,80	133	0,38	0,28
2009	1002	4,80	0,48	846	4,32	0,51	113	0,11	0,10
2010	2829	6,90	0,24	516	1,28	0,25	167	1,03	0,61
2011	2539	4,95	0,20	638	2,20	0,35	182	0,18	0,10
	Silver hake			Arctic cod			Sculpins (*Myoxocephalus*)		
	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey
	t	t	t (%)	t	t	t (%)	t	t	t (%)
2006	0	0,34	-	75	0,80	1,08	3785	0,05	0,001
2007	158	0,89	0,56	4	2,41	65,43	1580	0,59	0,038
2008	1325	0,55	0,04	24	0,12	0,51	2529	0,08	0,003
2009	162	0,17	0,11	15	2,88	19,50	1633	0,88	0,054
2010	258	1,31	0,51	153	0,97	0,63	4669	0,50	0,011
2011	1407	0,92	0,07	11	0,61	5,77	2955	0,42	0,014
	Snailfishes			Lumpsuckers			Wrymouth		
	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey
	t	t	t (%)	t	t	t (%)	t	t	t (%)
2006	238	0,54	0,23	170	0,06	0,04	181	0,004	0,002
2007	90	0,34	0,38	220	0,17	0,08	102	0,015	0,015
2008	233	1,09	0,47	191	0,15	0,08	375	0,845	0,225
2009	22	0,93	4,19	156	0,24	0,15	122	0,048	0,039
2010	1480	0,43	0,03	228	0,11	0,05	100	0,055	0,055
2011	97	0,33	0,35	133	0,09	0,07	181	0,067	0,037
	Rocklings (*Gaidropsarus*)			Hookear sculpins (*Artedellius*)			Sculpins (*Triglops*)		
	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey
	t	t	t (%)	t	t	t (%)	t	t	t (%)
2006	0.29	0,08	27,47	85	0,33	0,39	1288	0,22	0,02
2007	0.11	1,61	1460,76	60	0,02	0,04	815	0,06	0,01
2008	0.03	0,66	2072,48	57	0,09	0,15	789	0,69	0,09
2009	0.26	0,11	41,56	25	0,22	0,86	1031	0,20	0,02
2010	29.03	0,11	0,37	55	0,01	0,02	977	0,16	0,02
2011	0.39	0,003	0,69	50	0,05	0,09	871	0,28	0,03
	Atlantic wolffish			Longfin hake			Spotted wolffish		
	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey	Survey	Bycatch	Bycatch/survey
	t	t	t (%)	t	t	t (%)	t	t	t (%)
2006	268	0,05	0,02	365	0,16	0,04	10	0,02	0,23
2007	190	0,46	0,24	603	0,33	0,05	0	0,12	-
2008	263	0,06	0,02	917	0,35	0,04	10	0	0
2009	134	0,04	0,03	208	0,39	0,19	7	0	0
2010	235	0,07	0,03	294	0,05	0,02	40	0,02	0,04
2011	75	0,13	0,18	560	0,16	0,03	33	0,08	0,24

Invertebrates

Invertebrates are represented by taxa grouping together shrimps, two of which are identified to the species level, and crabs, three of which are identified to the species level. Squids, octopuses and sepiolas, starfishes, sea urchins and brittle stars, sea cucumber, bivalves, jellyfishes and anemones complete the invertebrate taxa. Squids are caught in more than 10% of observed tows. Squids are pelagic and their presence in the Gulf varies from year to year. The survey is not suitable for estimating biomass by the swept area method because their catchability is low. White shrimp (*Pasiphaea multidentata*) and striped shrimp (*Pandalus montagui*) are species found regularly with *Pandalus borealis*, and their bycatches total 240 t and 69 t, respectively, over 12 years. Invertebrates that are harvested in the Gulf and found in bycatches are snow crab (1.5 t over 12 years), rock crab (0.1 t) and sea cucumber (0.3 t). Their bycatches are much lower than their commercial landings. Bycatches of the other invertebrates that are not harvested totaled only a few tons over 12 years.

Vulnerable species

Three taxa are considered vulnerable in accordance with the FAO guidelines in response to UN Resolution 61/105. These are sponges, sea pens and gorgonian corals. Special effort has been made to record their catches since 2008 (Table 1). Sponge catches were noted in 30 tows and totaled 640 kg over five years. Sea pens were caught in 36 tows and their bycatches were estimated at 787 kg over five years. Gorgonian coral catches are rare. They were caught in only two tows for an estimated catch of 36 kg.

Species at risk

At the time of this analysis, species protected under the *Species at Risk Act* that are present in the Gulf of St. Lawrence are the spotted wolffish, the Northern wolffish, the leatherback turtle and the striped bass (St. Lawrence Estuary population). No leatherback turtle specimens were caught between 2000 and 2011. Striped bass were caught in one tow in 2003 (Table 1). The bycatch for the entire fleet weighed 14 kg. Northern wolffish were caught in six fishing tows in 2005, 2007 and 2010 (Table 1). The total bycatch was 234 kg. Spotted wolffish were caught more regularly between 2000 and 2011 in 52 tows and the total estimated bycatch for all the shrimpers was 909 kg over the 12 years studied (Table 1). The bycatches of the two species of wolffishes represent less than 0.24% of survey biomass estimates (Table 4).

Impact of bycatches

When groundfish are compared to northern Gulf populations, bycatches represent less than 1% of the numbers and the biomass for the most part. Additional mortality caused by the shrimp fishery is low and should not have had an impact on the Estuary or northern Gulf populations. A total instantaneous mortality rate (Z) of 0.2 corresponds to mortality of 18.1% of the population in one year whereas a mortality rate of 0.5 corresponds to 39.4% mortality. An additional mortality of 1% of the numbers would result in a total mortality increase of 0.2% if Z=0.2, and of 0.4% if Z=0.5. Bycatches in the shrimp fishery contribute to an increased mortality of these species, but this increase is marginal in relation to the normal mortality rate for juveniles and adults in these populations.

For the pelagic fish harvested, bycatches remain well below the annual landings observed in the northern Gulf. In the case of invertebrates (present in less than 4% of the tows observed, with the exception of squid and shrimp), vulnerable species (found in less than 0.25% of the tows) and species at risk (found in less than 0.4% of the tows), bycatches cannot be compared to population numbers or biomass. However, bycatches are considered marginal in relation to the

northern Gulf populations because they range from a few specimens to a few hundred kilograms per year.

Sources of uncertainty

Observer data are a unique source of information on at-sea shrimp fishing operations. However, there is uncertainty regarding the identification of specimens caught, the consistency in the effort to identify less important species over the studied period, and the weight of very small catches. Identification errors or an irregular identification effort can have an impact on the total estimate of the species bycatch because there some species can be confused with others. Lesser-known species may not have been identified over the first half of the 2000s. Also, very small catches were systematically recorded as 1 kg. This lack of precision could overestimate the bycatch, especially for species that are not abundant and whose catches are usually made up of few specimens.

CONCLUSIONS

Bycatches in the shrimp fishery are frequent and diversified. Bycatches were grouped under 97 taxa, 77 of which were fish and 20 of which were invertebrates. Bycatches were observed in all fishing tows. However, they are insignificant in relation to the catch of the targeted species because the bycatch ratio represents between 1.0 and 2.3% of Northern Shrimp catches per year for the 2000–2011 period.

Bycatches in the shrimp fishery remain low and should not have had an impact on Estuary or northern Gulf populations. Bycatches contribute to an increase in mortality, but this increase is marginal in relation to the normal mortality rates among these populations.

SOURCES OF INFORMATION

This Science Advisory Report is from the Regional Science Advisory Meeting of October 23, 2012 on the Importance of Bycatch in the Northern Shrimp Fishery in the Estuary and Northern Gulf of St. Lawrence. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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